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A Novel Water Quality Monitoring System Based on Solar Power Supply & Wireless Sensor Network

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Abstract

This paper presents a water quality monitoring system using wireless sensor network (WSN) technology and powered by solar panel. In order to monitor water quality in different field sites and in real-time, a novel system architecture constituted by several distributed sensor nodes and a base station is suggested. The nodes and base station are connected using WSN technology. A prototype system using one node powered by solar cell and WSN technology is designed and implemented. Data collected by various sensors in the node side such as pH, turbidity and oxygen density is sent via WSN to the base station. The system has advantages such as low carbon emission, low power consumption, more flexible to deploy and so on.

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Keywords: Water quality monitoring; Environmental friendly; WSN; Solar power; Real-time

1. Introduction

Nowadays, 20% of the world population does not have safe water for drinking. The situation is even worse in some developing countries, where dirty or contaminated water is used for drinking without properly treated. One of the reasons for this situation is the lack of water quality monitoring system. Using different sensors, these systems can collect various environmental parameters from water, such as temperature, pH, oxygen density, turbidity and so on. The rapid development of wireless sensor network (WSN) technology provides us a novel approach to real-time data acquisition, transmission and processing. The users can get real time water quality data from faraway. In a system of this kind, there are several nodes and a base station. Each node contains a group of sensors and the nodes are distributed in different water bodies. Data collected by sensors is sent to the base station via WSN channel. The base

station is usually a PC with Graphic User Interface (GUI) for users to analyze water quality data or alarm automatically when water quality detected is below preset standards. [1][2][3]

In a practical water quality monitoring system, where sensor nodes are distributed in remote sites, power supply has become an extremely important issue, sometimes even the bottleneck of the system. Using wires to connect nodes to power lines nearby is not practical, because the nodes usually distribute in remote places, and the total expense in connecting all these nodes is unbearable. Another method is to use battery only. The advantages are obvious, but batteries have lifespan and cannot stand for a long time. Replacing depleted batteries regularly is inconvenient. To avoid unnecessary work and make the system more flexible to deploy, solar panel is used in this system to supply power to the sensor node, together with an accumulator to recharge when solar power is not enough, such as night. The system has advantages such as low carbon emission, low power consumption, more flexible to deploy and more intelligent, which represents the trends of next-generation water monitoring. [5]

2. Overall system design

The water quality monitoring system proposed is made up by a base station and several sensor nodes. The sensor nodes are located in different sites where we need to monitor water quality. The base station contains a wireless receiver and a PC, where users can receive data from sensor nodes and analyze it. The base station can still connect to Ethernet so that users can login and get data faraway. The nodes and base station are connected via WSN technology. Figure 1 below shows the overall architecture of the monitoring system.

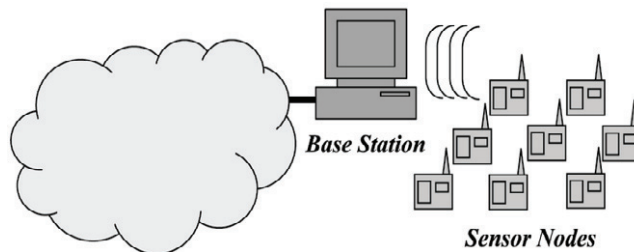


Fig. 1 Overall System Architecture

To fulfill features of solar power supply and multi-sensing, each sensor node in this system is constituted by four modules: solar power, sensor, interface circuit and SunSPOT. The first one is solar power module, which uses solar cell to provide power to other modules. In sensor module, 3 types of sensors are used: Turbidity sensor, Redox probe and pH probe. Interface circuit module transfers voltage output from solar power module (+12V) to +9V and $\pm 5V$ separately, while turbidity sensor OBS-3+ is powered by +9V and other sensors are powered by +5V. Some op-amps use $\pm 5V$ dual power. Interface circuit also receives data obtained by sensors and sends it to SunSPOT, a wireless module powered by +5V. SunSPOT (Sun Small Programmable Object Technology) is a WSN transceiver based on IEEE 802.15.4 standard [7]. It is developed by Sun Microsystems. In this system, SunSPOT is used to transmit data to the base station through WSN. Thus data can be received and analyzed in base station by users. Figure 2 below presents the detailed block diagram of a sensor node.

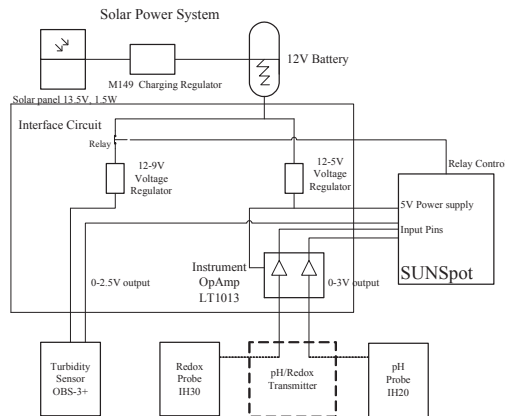


Fig. 2 Detailed Block Diagram of a Sensor Node

3. Detailed hardware design

This part discusses the detailed hardware design of some modules, especially the solar power module and interface circuit module. The solar power module contains a solar panel, a regulator and an accumulator. The rated output voltage and power of the solar panel is 13.5V, 1.5W, as the total power consumption of the sensor node is much smaller. The output voltage of solar panel changes as external light intensity differs, and is usually smaller than 13.5V. Because the sunlight changes day and night, an accumulator with 12V output is needed to stabilize the output voltage of the solar power module. A regulator is connected between the solar panel and accumulator. When the sunlight is strong and solar panel outputs higher than 12V, the regulator turns on, thus solar panel powers other blocks and the accumulator is charging. When the sunlight is weaker so that the solar panel voltage is lower than 12V, the regulator turns off, thus the whole sensor node is powered by 12V output of the accumulator. Figure 3 below shows the detailed diagram of solar power module.

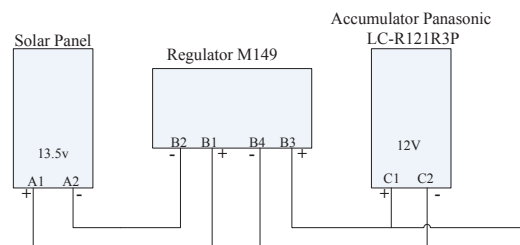


Fig. 3 Detailed Design of Solar Power Module

After the solar power module generates 12V DC voltage, a power interface circuit is needed to transfer this voltage to +5V and +9V. L7805/7809 voltage regulator is used in this circuit. The schematic is shown in figure 4.

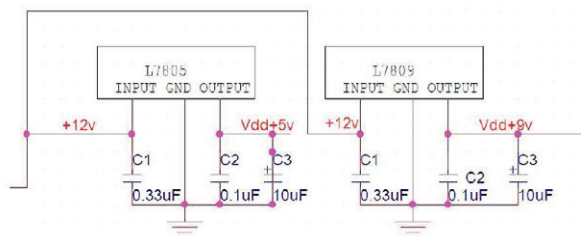


Fig. 4 Power Interface Circuit Schematic

The pH probe IH20 used in this system is a high accuracy pH sensor which has output voltage from -412mV to 412mV. The theoretical output of the IH20 pH probe is approximately 59.16 mV/pH at 25°C, i.e. 7pH = 0mV, 8pH = -59mV, 9pH = 2 x -59mV. (-mV=Alkali, +mV= Acid), so the range is roughly +413 mV to -413 mV for 0pH to 14pH. This output voltage is affected by environmental temperature. To compensate the temperature factor, a temperature compensating resistor (R2 in the below figure) is placed in the feedback loop to cancel the temperature dependence of the probe. The circuit transfers IH20 output voltage to 0~2.5V range proportional and sends it to SunSPOT. The following figure is a schematic of interface circuit for pH probe IH20.

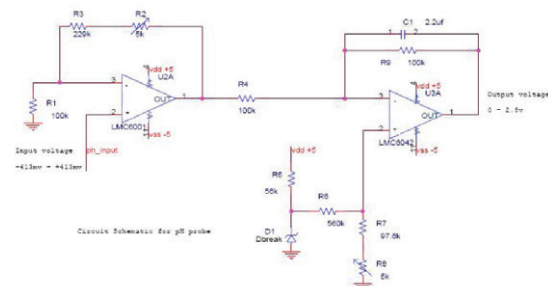


Fig. 5 pH Interface Circuit Schematic

Redox sensor is used to measure the density of oxygen in water. Its probe generates a voltage proportional to the amount of free halogen in the water, from 0mV to 1000mV. The difficulty of measuring voltage across these probes is that the output impedance of the probe is very high, so a high input impedance component is chosen to match it. On the other hand, the SunSPOT's analog input pins (A0, A1, A2, and A3) accept a 0-3V analog signal. Hence an amplifier conditioning circuit is needed to output voltage in the range of 0-3V.

The Redox interface circuit is shown on figure 6.

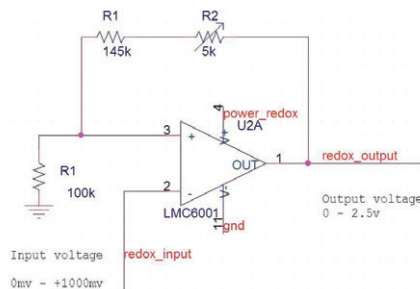


Fig. 6 Redox Interface Circuit Schematic

Turbidity sensor is to measure the clarity of water, the output voltage range is responding to turbidity value ranging from 0 to 4000NTU (Nephelometric turbidity unity) .Output signal is transferred from 0~5v to 0~3v.

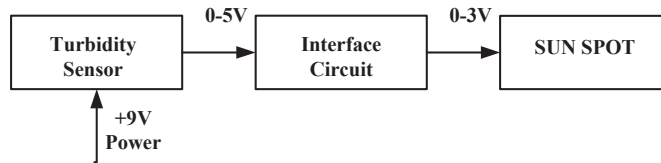


Fig. 7 Turbidity Interface Circuit Block

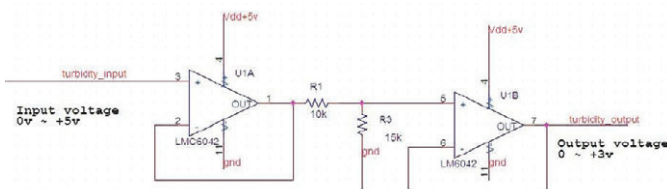


Fig. 8 Detailed Turbidity Interface Circuit

4. Software design

As discussed before, data communication between the sensor node and base station is fulfilled by SunSPOT, a programmable WSN transceiver. The software communication architecture is designed based on SunSPOT. It is divided into two parts: data receiver and sender. Figure 9 presents the flow chart of an acknowledgement receiver.

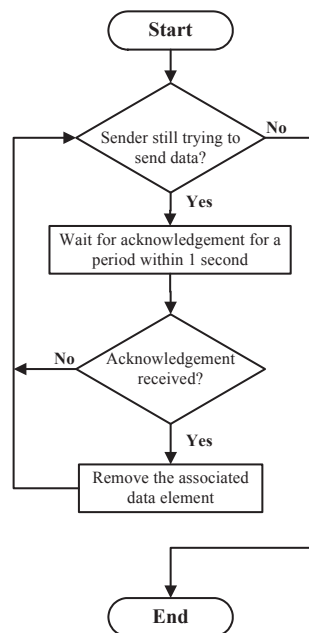


Fig. 9 The Acknowledgement Receiver

The data transferring process is implemented as a monitor pattern. The monitor controls access to the shared data set, which is a hash table that contains the time stamp of the measurement as key, and the measurement itself as a sample value. Concurrently, a data sender does the sending process, with an acknowledgement receiver listens for any acknowledgments that it can receive from the base station.

When the data sender or the acknowledgement receiver wants to access the shared data set, they should ask the monitor for access permission. As the acknowledgement receiver receives acknowledgement message, which is identified by its key value, the receiver removes the associated element from the data set. The data sender will stop trying to send data when all the data elements have been acknowledged or have already tried for a specified number of trials. The flow chart of the acknowledgement receiver and the data sender are illustrated by Fig.9 and Fig.10 respectively.

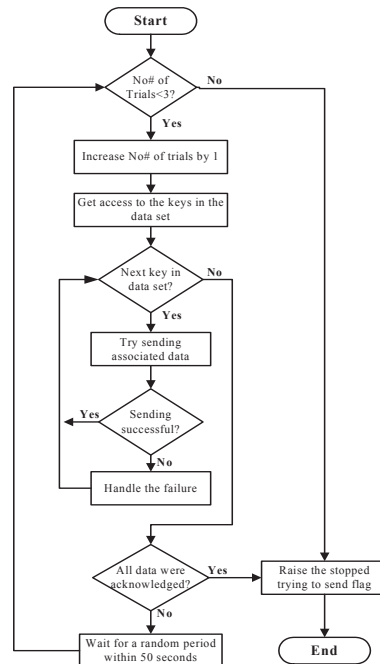


Fig. 10 The Data Sender

Since the sensor node works in field and is powered by solar panel, its power consumption is limited. A deep sleep mode which consumes power much less than normal is proposed in the node. The sensor node can be transferred to deep sleep mode and wake up easily. Going to deep sleep is affected by the background processes in the Java virtual machine running on the SunSPOT. The algorithm is about how to go to deep sleep correctly in the presence of background processes. For example, the current time is used to calculate the next wake up time, given required sleeping period. Then, as long as the current time does not pass the next wake up time, the SunSPOT either goes to deep sleep for the minimum deep sleep interval, in case of no background process, or it tries to go to deep sleep until the next wake up time, in case of background process. Finally, if there is an unexpected event that prevents it from going to deep sleep, or even makes it sleep for a shorter time, the sleeping trial will just start again. This process is illustrated by Fig.11.

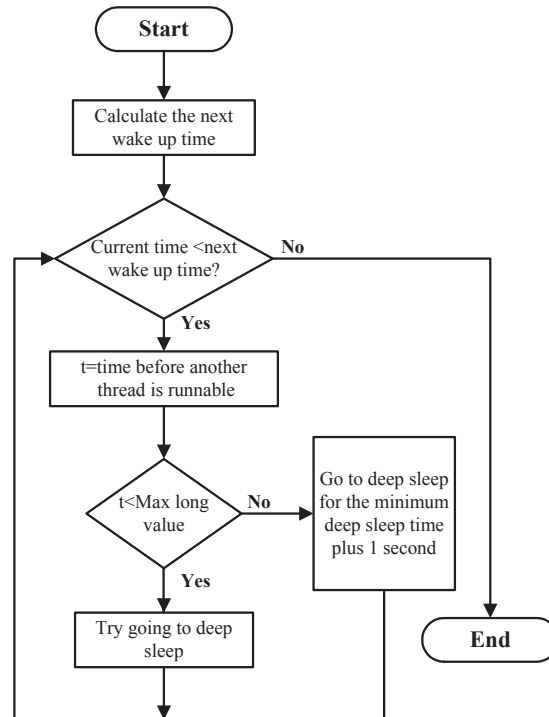


Fig. 11 The Sleeping Control Process

5. Implementation

Figure 12 shows the graphic user interface (GUI) window in the base station side. In this window, real time water quality data sent from the sensor node and received by the base station is presented. Note that 6 water samples are tested; their pH and turbidity values are shown in this figure.

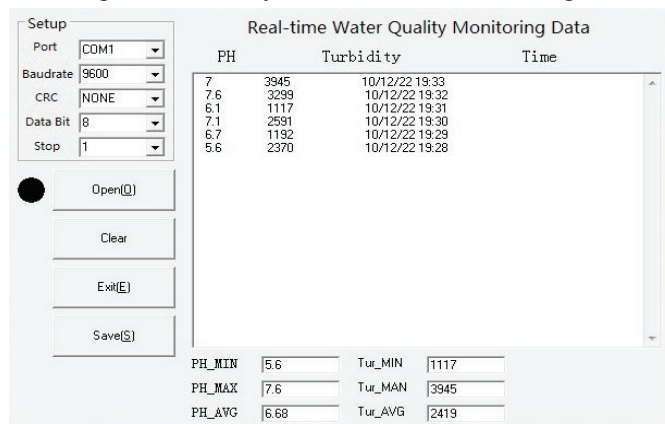


Fig. 12 Real-time Monitoring Data in GUI

6. Conclusion & future works

In this paper, a novel water quality monitoring system based on wireless sensor network is presented. The system is constituted by a base station and several sensor nodes. The sensor nodes are powered by solar power module, while data connection between the node and base station is realized using WSN technology (IEEE 802.15.4). In the node side, water quality data is collected by different sensors such as pH, oxygen density and turbidity. This data, after voltage conversion by interface circuit, is sent to SunSPOT for wireless transmitting. This paper also presents detailed hardware design of several modules in the sensor node, together with general software flow charts of the acknowledgement receiver and data sender used in transmission. The data transceiver is integrated in SunSPOT and is programmable. Finally, the prototype system with a single sensor node and base station is designed and implemented. Real-time water quality data can be seen from a GUI window in PC. The system has advantages such as low carbon emission, low power consumption, more flexible to deploy and so on.

In order to monitor water quality in different sites, future works can be focused on establishing a system with more sensor nodes and more base stations. Connections between nodes and base station are via WSN, while connections among different base stations are via Ethernet. The Ethernet can also be connected to Internet so that users can login to the system and get real time water quality data faraway. Another interesting field lies on the optimization of power consumption and data throughput of the WSN.

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